Fennoscandia archaeologica XXXI (2014)

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THE MERE POSSIBILITY OF BIASES DOES NOT INVALIDATE ARCHAEOLOGICAL POPULATION PROXIES – RESPONSE TO TEEMU MÖKKÖNEN

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We wish to thank Teemu Mökkönen for opening the discussion on archaeological population proxies in Finnish archaeology. Mökkönen raises many important issues that can bias archaeological population proxies. The important question is whether these possible biasing factors really have any effect. In our understanding, Mökkönen's main criticism can be summarised as follows:

There is no positive correlation between the temporal frequency distribution of archaeological 14C dates and prehistoric population size because:

1) there is no correlation between the distributions of 14C dates and known archaeological material (due to different research interests, more dates are known from some archaeological periods than others, i.e., the distribution of the dates is biased)
2) natural forest fires have a marked influence on 14C dates of charcoal samples and thus on the shape of the distribution of 14C dates
3) the temporal distribution of known archaeological material is determined by the current visibility of archaeological material and not by the actual volume of archaeological material existing 'out there'.

Critique is essential for scientific advancement. At best, it can lead to important modifications of existing theories and methods and to the rise of new paradigms. In order to be sound, scientific critique has to be based on relevant evidence and/or logical thinking. Below, we show that neither of these elements is very well represented in Mökkönen's argumentation against archaeological population proxies published by us and others.

Figure 1 shows all the proxies and other indicators of prehistoric human population size which, to our knowledge, have been presented in Finnish archaeology. They are shown in the format in which they were originally published or as slightly modified versions. Most of them are based on the idea that there is a positive correlation between the number of people or density of the population and the total amount of archaeological material they left behind (sites, hearths, tools, etc.) or some other relevant variable. All the indicators shown in Figure 1 are also familiar to Mökkönen according to the references in Mökkönen (this volume) and Mökkönen (2011).

Figure 1A shows the temporal distribution of 14C dates from Finland published in Tallavaara et al. (2010), presented here as a temporal frequency distribution of calibrated median dates with 100 year bins. Dates are calibrated using IntCal13 calibration curve (Reimer et al. 2013) and clam 2.2 calibration algorithm (Blaauw 2010) in R (R Core Team 2014). As Mökkönen mentions, Tallavaara et al. (2010) used the distribution of sites that were dated using ceramic typology as an alternative proxy that is independent of the frequency of 14C dates. This ceramic site frequency index is presented in Figure 1B.

Siiriäinen (1981) presented a distribution of coastal sites dated using shore displacement chronology. He assumed that the distribution (num-

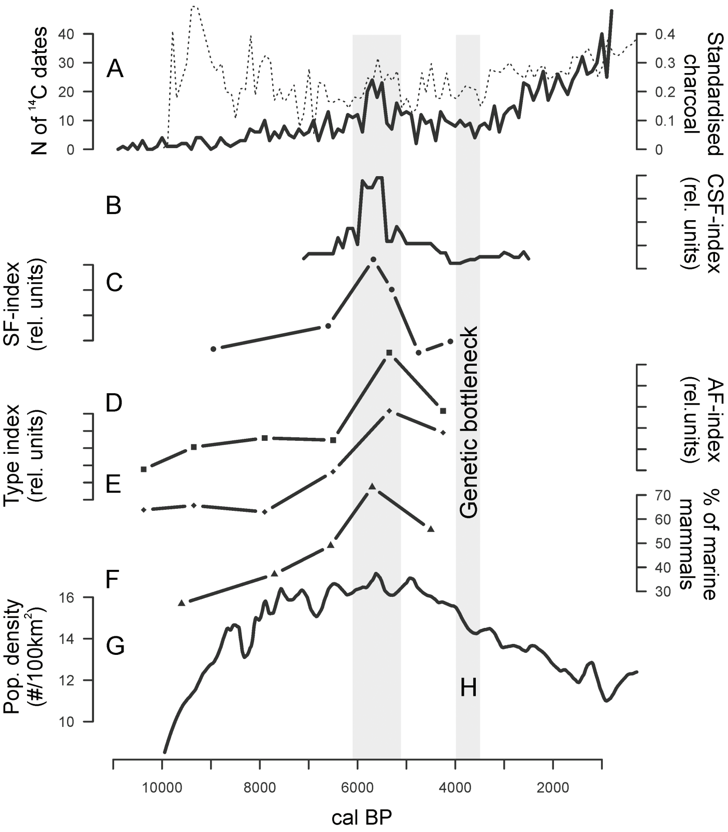

Fig. 1. Different proxies and indicators of prehistoric population size in Finland. A: Temporal frequency distribution of archaeological 14C dates (Tallavaara et al. 2010; Oinonen et al. 2010). Dotted line shows the forest fire record (standardised charcoal) according to Clear et al. (2014). B: Ceramic site frequency index that shows the distribution of sites dated typologically using ceramic finds (Tallavaara et al. 2010). C: Distribution of the number of coastal sites (Siiriäinen 1981), adjusted for the length of each period. D: Distribution of the absolute number of stone artefacts assigned to a given period (Sundell 2014), adjusted for the length of each period. E: Distribution of the number of different artefact types associated with each period (Sundell 2014), adjusted for the length of each period. F: Percentage of marine mammal bone fragments in coastal archaeological bone assemblages. For original application, see Hertell (2009). G: Simulation of hunter-gatherer population density (Tallavaara & Seppä 2012). H: Timing of the genetic bottleneck inferred from Finnish genetic data (Sajantila et al. 1996). The figure also highlights the Mid-Holocene period that shows a strong signal in every archaeological proxy.

ber of sites per 100 years) reflects changes in human population size. Siiriäinen's curve of site frequency is presented here in such a way that the time boundaries of different cultural periods are updated according to current knowledge (Fig. 1C).

Recently, Sundell (2014) used the number of stone artefacts and number of stone artefact types in a given period as a human population proxy. Here, the artefact frequency (Fig. 1D) and number of types (Fig. 1E) in a given period are divided by the length of the period to account for the varying durations of different cultural periods.

In his study of the beginning of agriculture in Finland, Hertell (2009) used the percentage of seal bones in coastal assemblages as a proxy for human population density. This is based on the fact that in the ethnographic record there is a positive correlation between hunter-gatherer population density and the proportion of aquatic resources in the diet (e.g. Kelly 1995; Binford 2001). Here we use the same idea, but with a larger dataset (osteological archives compiled by Pirkko Ukkonen and Kristiina Mannermaa at the Finnish Museum of Natural History and unpublished osteological reports at the National Board of Antiquities) and a different periodisation: Early Mesolithic (11000–8500 calBP), Late Mesolithic (8500–7200 calBP), Early Neolithic (7200–6000 calBP), Middle Neolithic (6000–5400 calBP), and Late Neolithic (5400–3500 calBP). Assemblages were dated using information from ceramic and 14C date databases. Hertell (2009) used the percentage of marine mammals among all sites in a period. This approach can be strongly influenced by only one outlying assemblage. Therefore we use here the mean percentage of marine mammal bone fragments per period (Fig. 1F).

In addition to archaeological proxies, Figure 1 shows population indicators that are independent of the archaeological record. Figure 1G is a simulation of hunter-gatherer population density. It is created using a transfer function that is based on information on how annual mean temperature affects hunter-gatherer population densities in the ethnographic record (Tallavaara & Seppä 2012). This simulation indicates how hunter-gatherer population density would have varied if the temperature, which affects environmental productivity and thus food availability for hunter-gatherers, had been the only driver of long-term population dynamics. This kind of simulation requires information on past annual temperatures, which in this case is acquired from pollen-based temperature reconstructions (Seppä et al. 2009; Tallavaara & Seppä 2012). Figure 1H shows the timing of the genetic bottleneck inferred from Finnish genetic data and dated using a molecular clock (Sajantila et al. 1996). To put it simply, a genetic (or population) bottleneck means that before and after the bottleneck, the effective population size has been larger than at the bottleneck (for more about prehistoric population bottlenecks, see Sundell 2014).

The proxies can be divided into three groups: 1) proxies tracking temporal changes in the amount of archaeological material (Figs. 1A–D), 2) archaeological proxies that are not dependent on the amount of archaeological material (Figs. 1E&F), and 3) proxies that are independent of the archaeological record (Figs. 1G&H).

Figure 1 clearly shows that, at least for the Stone Age part, the temporal frequency distribution of 14C dates follows the distribution of other proxies tracking the amount of archaeological material (Figs. 1B–D). This suggests that the distribution of 14C dates is not biased in relation to the distribution of known archaeological material in Finland.

In addition, Oinonen et al. (2010) compared the temporal distribution of dates to a reference distribution obtained by selecting only dates of individual samples submitted by the National Board of Antiquities. These are typically due to rescue excavations mostly free of research interest-induced biases. Strong correlation (r=0.87) exists between such a distribution and the full data. This similarity builds further confidence on interpreting the observed date distribution as reflecting the observed distribution of archaeological material. Thus, instead of defining the radiocarbon frequency distributions as 'based on what researchers sample, not what exists…', we would prefer more constructive approach: radiocarbon frequency distributions are based on what large number of researchers sample, and thus reflect the present timeline of the past human activity.

Mökkönen's argument that natural forest fires have significantly contributed to the distribution of 14C dates, especially to the Mid-Holocene peak between 6000 and 5000 calBP, appears problematic. To argue that the temporal distribution of archaeological charcoal samples is strongly influenced by forest fire frequency, one must establish a correlation between the distribution of archaeological charcoal samples and the macroscopic (dateable) soil charcoal from randomly selected non-archaeological locations. The forest fire hypothesis requires that forest fire-related charcoal is generally abundant in soils – otherwise it cannot be found from archaeological sites either. Thus, contrary to Mökkönen's argumentation, the correlation between archaeological charcoal data and palynological sedimentary charcoal record alone does not indicate any causal link between forest fires and charcoal samples from archaeological contexts.

Another issue is that despite Mökkönen's claims, even the Holocene forest fire records based of charcoal data from sediment cores (Clear et al. 2014) does not show strong correlation with archaeological charcoal data (Fig. 1A). There is a peak in the forest fire record between 6000 and 5000 calBP, but there are other peaks as well that do not correspond to archaeological patterns.

Mökkönen also undermines the expertise of his own profession by claiming that many archaeological charcoal samples derive from forest fires, not from human agency. It is true that some charcoal dates may appear unrelated to archaeological material from the same context. However, in addition to the often disputed 'cultural layer charcoal', this also applies to samples from hearths, in which the charcoal can hardly be thought to result from forest fires. Many other radiocarbon dates also show unexpected and even unwanted values. The reason for the 'unsuitable' radiocarbon dates may actually be based on human agency that is simply invisible in the archaeological record otherwise (e.g. Pesonen & Tallavaara 2006).

Nevertheless, even if one is able to demonstrate similarity between temporal distributions of randomly selected soil charcoal and archaeological charcoal samples, one cannot conclude that forestfire frequency determines the distribution of archaeological proxies in our case. This is because of the fact that proxies that are independent of the frequency of 14C dates (Figs.1 B–F) show the same general shape as the distribution of 14C dates. Forest fires could not have influenced these other proxies. The similarity between proxies suggests that it is unlikely that forest fires would have significantly affected the shape of the 14C date distribution either.

However, as Mökkönen argues, it is possible that the temporal variation in the amount of known archaeological material is profoundly influenced by the visibility of archaeological cultures. If this were the case, then one must assume that the visibility of archaeological material increases at the beginning of the Bronze Age / Early Metal Age as the frequency of 14C dates starts to increase again. Yet it is known that after the Stone Age, the number of house pits and house pit sites decreases (Pesonen 2002) and ceramics become even less visible (Ikäheimo 2002). Thus, we would expect to see a decrease in the frequency of 14C dates after the Stone Age, if the visibility of archaeological material were an important driver of the temporal distribution of archaeological material.

Furthermore, as Oinonen et al. (2010) have shown, the pattern in the temporal distribution of 14C dates has remained the same throughout the history of radiocarbon dating in Finland (Fig. 2). The pattern was the same in the 1970s and 1980s as it is today. It is the same also in Siiriäinen's (1981) curve that is based on data gathered before 1969.Thus, while the boom in the research of house pits and the beginning of Petro Pesonen's active career in the 1990s contributed in the whole dataset, they did not have any profound influence on the shape of the distributions of archaeological material and 14C dates.

In addition, the archaeological proxies independent of the temporal distribution of the archaeological material (Figs. 1E&F) show a pattern similar to that of the 14C dates. Because these proxies do not track changes in the amount of archaeological material, they are not affected by the possibility that sites belonging to certain periods are more easily found than sites belonging to other periods. Therefore, they are not influenced by the possible variations in archaeological visibility.

Mökkönen also discusses regional variation in 14C date distributions. He claims that the three regional curves (southern, central, and northern) published in Tallavaara et al. (2010) show opposing trends. It is true that in northern Finland the pattern is clearly different from the rest. However, the patterns in the southern and central areas are highly similar. Both show a clear Mid-Holocene boom and bust pattern followed by a new rise at the beginning of the Bronze Age. Mökkönen is mistaken when he further claims that Tallavaara & Seppä (2012) used the whole 14C dataset in their study on the effects of the environment on human population dynamics. Instead, Tallavaara & Seppä (2012) used 14C data only from the southern and central regions and palaeoenvironmental data from eastern, southern, and central Finland. In their study, northern Finland was deliberately excluded because there the population proxy does not show any boom and bust pattern, which was the main focus of their study. It is also possible that the timing of the Holocene thermal maximum differs between southern (Heikkilä & Seppä 2003; Ojala et al. 2008) and northern (Seppä & Birks 2001; 2002) Fennoscandia.

Apart from the issues of regional variation, Mökkönen's critique is basically relevant in the sense that the issues he raises can cause bias in interpretations of temporal frequency distributions in the archaeological material. The mere

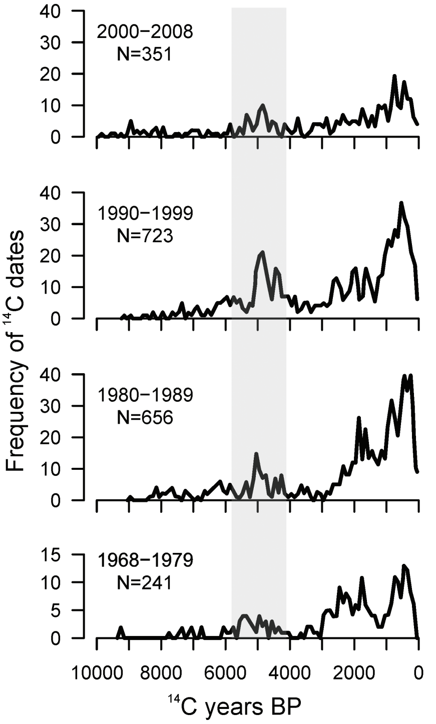

Fig. 2. Distribution of 14C dates analysed at the Dating Laboratory/Laboratory of Chronology of the Finnish Museum of Natural History, University of Helsinki (Hel- and Hela-dates) and grouped according to the submission decade. The figure also highlights the Mid-Holocene period showing a strong signal throughout the history of 14C dating in Finland.

possibility of biases, however, does not qualify as a proper scientific critique and Mökkönen does not support his arguments with relevant evidence or reveal logical fallacies in our argumentation. In previous publications, we have already shown that many of the possible biases Mökkönen now raises can be refuted or had only a minor role in shaping the temporal distribution of archaeological 14C dates. Here, we have used mainly evidence that has already been published and we have shown that the main points of Mökkönen's arguments are not valid: the temporal frequency distribution of 14C dates is not biased in relation to the rest of the known archaeological material and it is unlikely that forest fires or visibility issues have significantly influenced the shape of the 14C date distribution.

Even if Mökkönen's critique is not valid, there could still be unknown factors that disturb the link between archaeological proxies and past population levels. However, one should not forget the evidence that is totally independent of the archaeological record. The population simulation (Fig. 1G) based on the ethnographically known correlation between annual mean temperature and hunter-gatherer population density shows the same general pattern as the archaeological proxies: a rise that culminates slightly after 6000 calBP followed by a decline. The deviation between the simulation and the archaeological proxy at the beginning of the Bronze Age occurs when agriculture starts to gain a stronger foothold in Finland. It is likely that the adoption of a farming economy broke down the link between climate and long-term human population dynamics (Tallavaara & Seppä 2012). In addition, the human genetic evidence on population bottlenecks (Sajantila et al. 1996) indicates that population size declined towards the end of the Stone Age and started to grow again afterwards (Fig. 1H), providing further independent support for the population pattern reflected in the archaeological proxies.

In the study of prehistory, it is very rare to have a number of such independent proxies. In this case, we have several independent archaeological and non-archaeological records and they all reflect the same pattern. This is a strong indication that these proxies are tracking a real prehistoric demographic signal.

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